Winds of change: expanding renewable energies in developing countries

Valorisation Addendum

In accordance with article 23.5 of the "Regulation governing the attainment of doctoral degrees at Maastricht University" decreed by resolution of the Board of Deans, dated 3 July 2013, an addendum must be added about valorization.

Relevance

An increasing world population combined with a rapidly rising material and per capita energy consumption is creating an ecological deficit, where roughly 1.5 planets are required to provide the necessary resources (Global Footprint Network 2015). The overarching motivation behind conducting the research in this thesis comes from the urgent need to reduce natural resource consumption to levels that can support human life and development in the future.

Reducing fossil fuel-based energy consumption that is contributing to climate change represents one important strategy to reduce its impacts and the ecological deficit. The importance of this strategy has been emphasized in goal 7 of the United Nation's *Sustainable Development Goals (SDGs)*, which aims to: *Ensure access to affordable, reliable, sustainable and modern energy for all*. In addition, the Climate Change Paris Agreement, signed in 2015 and ratified by 169 out of 197 parties, has as an ambition to combat climate change. Expanding access to and the use of renewable energy technologies is considered one significant component in achieving that goal.

Meeting the goals of reduced emissions requires a rapid and successful expansion of a wide range of mitigation alternatives. This thesis has focused on increasing the knowledge regarding the driving and obstructing mechanisms for expanding renewable energy technologies (RETs), with a special focus on developing countries. The thesis does this through a combination of conceptual and empirical chapters, including a study on wind energy adoption in Colombia. The focus on developing countries is particularly relevant as projections to 2040 show that energy use is expected to grow substantially, predominately in non-OECD countries (>85% of the increase), as a result of population increase, economic growth and higher standards of living (EIA 2013). Global projections estimate that global emissions in developing or emerging countries will exceed that of the developed world in the next decades (EIA 2013). At the same time, approximately 1.2 billion people are without access to any form of electricity and without successful policy interventions, 1 billion people are still expected to be without electricity in 2030 (IEA 2015). Worst off is Sub-Saharan Africa, with data from 2014 demonstrating that only 35% of the population has access to electricity, with as little as 19% in rural areas (IEA 2016b). Beyond the positive environmental

implications, given the low operation and maintenance costs, RETs could also be considered a principal instrument in alleviating energy poverty in developing countries (Bhide and Monroy 2011).

Due to the importance that an increased access to clean and affordable energy (SDG 7) can have on positively affecting other developmental issues, the relevance of the research in this thesis can also be found through a direct or indirect support of several other SDGs. For example, a supply of reliable and clean energy would contribute to the infrastructure that enables innovation and industry development (SDG 9) to occur. Consequentially, by facilitating the formation of new firms, work opportunities and reduced poverty (SDG 1) will followed.

Another example for how the research conducted in this thesis connects to other SDGs is its potential to reduce energy poverty in rural remote areas where the incentive to extend the national electricity grid is limited. As both schools and health clinics are dependent on a reliable source of electricity to provide quality education (SDG 4) and good health care (SDG 3), expanding RETs in these areas can play an important role in reaching these SDGs. Moreover, as has been discussed in this thesis, the expansion of RETs adoption represents one of the essential mitigation strategies for reducing green house gas (GHG) emissions (Climate Action-SDG 13).

In reducing the risk from conflict generated by climate change migration and energy insecurity, the relevance of the research conducted in this thesis can also be found in SDG 16 (peace, justice and strong institutions). In addition, in order to achieve sustainable cities and communities (SDG 11), an increased supply of electricity from RETs is pivotal to transition from a fossil fuel based transport sector to electricity-based vehicles, without increasing CO2 equivalent emissions and exacerbating climate change (SDG 13).

Innovation

This thesis proposes an extended technological innovation system function approach that can be considered innovative when compared with the earlier approach. Through the extended approach, this research has provided additional pathways to observe and understand the processes behind transitioning to renewable energy technologies. The thesis proposes a systematic and explicit inclusion of framework conditions, which would benefit future transition studies, both for high-income and developing countries.

Moreover, the evidence presented in this thesis suggests that the prominence and prevalence of relevant framework conditions is higher in developing countries, thus bringing attention to the importance of delimiting the system boundaries to include not only the technological innovation under study but also wider

framework conditions. In other words, the thesis suggests that a number of conditions that may exercise positive (contributing) or negative (hindering) effects on technological transitions, in this case RETs, should be regarded as endogenous rather than exogenous to the system. For example, in the extended TIS function analysis conducted in Colombia, which complemented the TIS function approach by systematically and explicitly analyzing the influence of framework conditions (landscape factors), revealed several interesting findings were revealed.

The thesis found both driving and obstructing influences from the landscape factors on the functions (integral actors and activities) of the system, with climate change demonstrating the strongest positive influence (i.e. contributing to adoption), and corruption and unequal access to quality education the strongest negative influence (i.e. obstructing adoption). More specifically, climate change related events, such as increased droughts (from a more severe El Niño) and ensuing water shortages were found to positively influence the wind energy sector, as existing energy regimes (the hydropower and thermoelectric sectors) faced deficiencies, resulting in increased pressure for the country to diversify its energy mix. Moreover, climate change was found to strongly contribute to the passing of several initiatives to expand wind energy and other RETs, such as the 'Low Carbon Development Strategy' and Renewable Energy (RE) Law.

Corruption, on the other hand, was found to block and/or slow down entrepreneurial activities and wind energy research projects, due to requests for informal payments at the local level. Unequal access to quality education largely explained the low access to skilled labor in remote rural areas of Colombia. Low access to skilled labor, in turn, reduced incentives for entrepreneurial activities in these areas. Paradoxically, many remote rural areas of Colombia have little or no access to electricity while having a high technical potential for wind energy, and could greatly benefit from electrification from Wind Energy and other RETs.

For the other landscape factors, i.e., economic growth, environmental awareness, and armed conflicts, a lesser but not insignificant influence could be identified. For example, while the armed conflicts led to a negative influence on new investments, e.g., through higher interest rates, energy generating companies regarded armed conflicts as a limited concern for new wind energy projects. Seeking approval and support for planned projects from the local community could also further reduce the risks from the armed conflict. For further details about the influence of landscape factors influence in Colombia, see Chapter 4.

Finally, the extended approach presented in this thesis expands the options of policies that are necessary to circumvent the barriers that are hampering the introduction and/or acceleration of clean energy alternatives, which can be considered an innovation compared with previous approaches used to analyze technological transitions.

By also discussing the innovation system approach from a broader perspective, the thesis has highlighted links between the TIS function approach and other approaches to measure innovation activities. One such link can be made between the *innovation activities* raised as part of the Oslo Manual (third edition) and the TIS functions, which could stimulate further research in the academic community to develop a more coherent approach to measure innovation in systems where RETs are present.

Target Groups

The research conducted in this thesis is relevant for both the academic community and policy makers and analysts in national governments or international organizations. For the national governments or international organizations working on projects to expand the use of renewable energy in developing countries, the result of the conceptual and empirical chapters in this thesis could inform decision-making and enhance policy design. For the academic community, the material presented could contribute to both the existing knowledge base for transition studies in developing and high-income countries, while adding to the ongoing effort to enhance the theoretical understanding of a technological system, its determinants and boundaries.

Dissemination

The results of this thesis (Chapters 3-6) will be disseminated to both academics and policy makers in Colombia and elsewhere that are engaged with energy policies and renewable energy adoption. Prior to the completion of this thesis, the key findings of Chapter 3 and 4 have been disseminated in international conferences, namely at the *14th Globelics International Conference* in Bandung (Indonesia) and the *6th International Sustainability Transitions (IST-6) Conference* in Brighton (UK), respectively.

In addition to being presented at international conferences, findings from Ch. 3 and 4 have been published as working papers and in peer-reviewed journals. Chapter 3, titled: *Technological Innovation System and the Wider Context: A framework for developing countries* has been published as a working paper at the UNU-MERIT working paper series in 2016 (Edsand 2016). Chapter 4, titled: *Identifying Barriers to Wind Energy Diffusion in Colombia: A Function Analysis of the Technological Innovation System and the Wider Context*, was published in 2017 in the journal Technology in Society (Edsand 2017). Chapter 5 (*The Impact of Environmental Education on Environmental and Renewable Energy Technology Awareness: Empirical Evidence from Colombia)* has been submitted to a peer-reviewed journal and is currently under review. In the time following the PhD, Chapter 3 and Chapter 6 (*Framework Conditions of Technological Transition: Re-thinking the*

Boundary for a Technological Innovation System) of this thesis will be submitted for dissemination through suitable peer-reviewed journals.